DOCUMENT RESUME

ED 189 443 CE 026 102

TITLE Electrical Experiments. VT-214-12-6. Part VI. Poly-Phase Alternators.
INSTITUTION Connecticut State Dept. of Education, Hartford. Div. of Vocational Education.
PUB DATE [77]
NOTE 31p.: For related documents see CE 026 095-102.

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Electrical Occupations: Electrical Systems: *Electricity: Learning Activities: Secondary Education: *Vocational Education
IDENTIFIERS *Alternators

ABSTRACT

Designed for high school electronics students, this sixth document in a series of six electrical learning activity packages focuses on phase alternators. An introductory section gives the objective for the activities, an introduction, and an outline of the content. The remainder of the guidebook is comprised of information sheets and job sheets on topics such as (1) poly-phase alternators, (2) operation and paralleling of alternators, and (3) synchronous motors. Each job sheet follows a typical format that includes the objective, materials, explanation, procedure, and evaluation questions. (LRA)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED189443

CONNECTICUT STATE DEPARTMENT OF EDUCATION
Division of Vocational Education
Hartford

ELECTRICAL EXPERIMENTS

VT - 214 - 12 - 6

PART VI

CE 026 102

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

F. S. Okula

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

POLY - PHASE ALTERNATORS

CONNECTICUT STATE VOCATIONAL SCHOOLS

POLY-PHASE ALTERNATORS

Contents

		No. of Pages
1.	Information Sheet: Poly-phase Alternators	1
2.	Job Sheet 1: Generating Poly-phase Currents	3
3.	Job Sheet 2: Three Phase Circuits-Balanced WYE Connected Load	2
4.	Job Sheet 3: Thre-Phase Circuits-Balanced Delta Connected Loads	2
5.	Information Sheet: Operation and Paralleling of Alternators	2
6,	Job Sheet 4: Parallel Operation of Polyphase Alternators	7
7.	Information Sheet: Synchronous Motors	2
8.	Job Sheet 5: Synchronous Motor Connection	5

POLY - PHASE ALTERNATORS

Information Sheet

Body of Information:

Generators that have more than one set of armature coil groups are called Poly-phase generators. If they produce alternating current they are usually called alternators. If the groups of armature coil groups are 120 electrical degrees apart it will be a three-phase alternator.

Alternators, if of small size, will usually have rotating armatures and slip rings and brushes to get to the output circuit. Larger alternators usually have rotating magnetic fields and stationary armatures. This is so the voltage is connected to the external circuit directly. The part of the alternator where the voltage is taken off is always the armature.

The field coils of an A.C. alternator must always have a D.C. voltage across them to produce the magnetic lines of flux to be cut by the armature to produce an alternating voltage at the armature output. The D.C. is usually produced by a small D.C. generator and is called an exciter.

The two main connections of a poly-phase alternator are the DELTA and the Y (or star) hook-up.

The three-phase generator is usually operated in a balanced condition: that is, the voltage across each armature coil is the same and so are the currents flowing through the coils. In the Y-connected alternator, the current in each coil line is the same as the armature coil it is connected to. It can be proved mathematically that the voltage between any two lines is equal to 1.73 times the voltage across one armature coil. (1.73 is the square root of 3).

In the balanced Delta-connected generator the voltage between any two lines is equal to that across any one armature coil. The current in each line, however, is 1.73 times the current in any one armature coil.

GENERATING POLY-PHASE CURRENTS

Job Sheet 1
Page 1 of 3

Objectives:

1. To learn to connect a three-phase alternator.
2. To note the differences between the Y-connected and the Star connected voltages at the lines.

Materials and Equipment Used:

Motor generator set (preferably a REM-LAB by Hampton Engineering) voltmeter. Connection wires.

Procedure:

1. Connect D.C. machine as a shunt motor through a Face-plate Starter.
2. Connect A.C. machine as a star-connected generator.
3. Excite A.C. fields with the correct D.C. field current.
4. Have circuit checked by instructor. Start D.C. motor.
5. Read A.C. voltage on the three A.C. lines.
6. Reconnect A.C. machine as a Delta-connected alternator and again read A.C. line voltage.

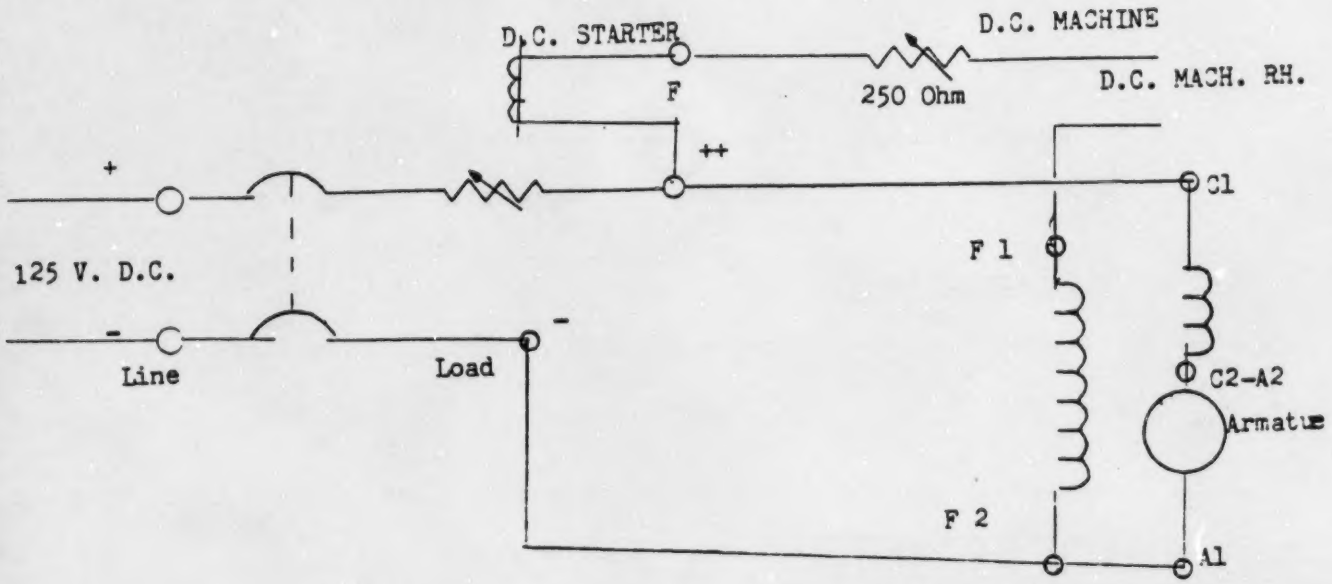
Questions:

1. Would there be an A.C. voltage output if there is no excitation voltage? Try it and explain your answer.
2. Why do the voltages differ between the Y and the Delta connection? Prove your answer.
3. Which connection of the alternator would be better for long-distance transmitting of high voltage A.C. in your opinion.

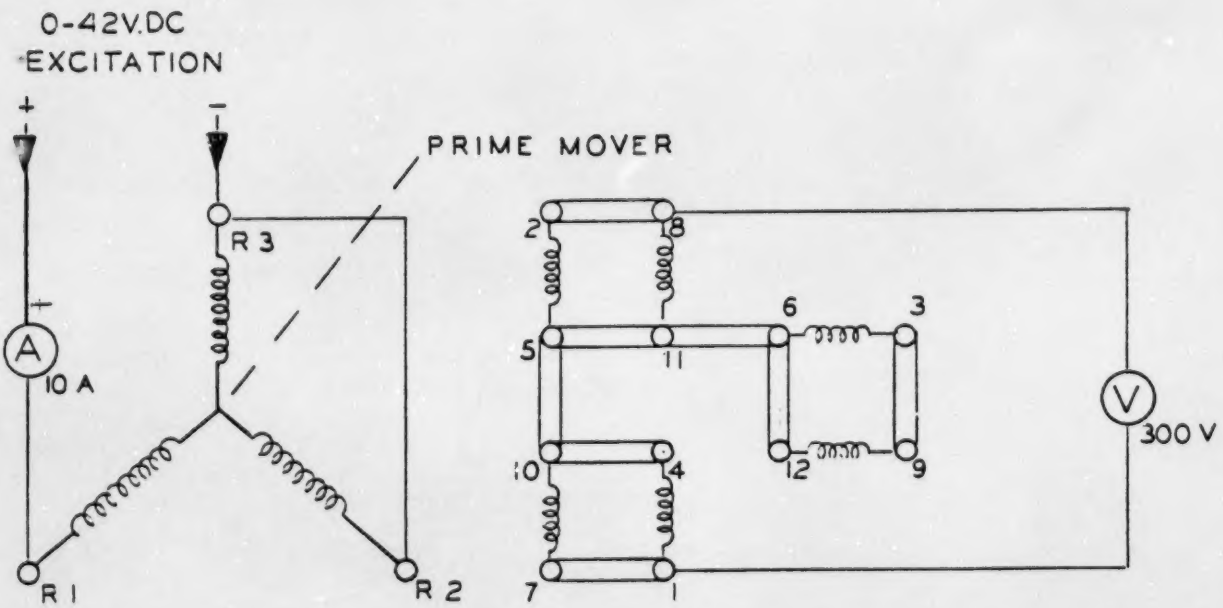
References:

Marcus: Electricity for Electricians. Prentice-Hall

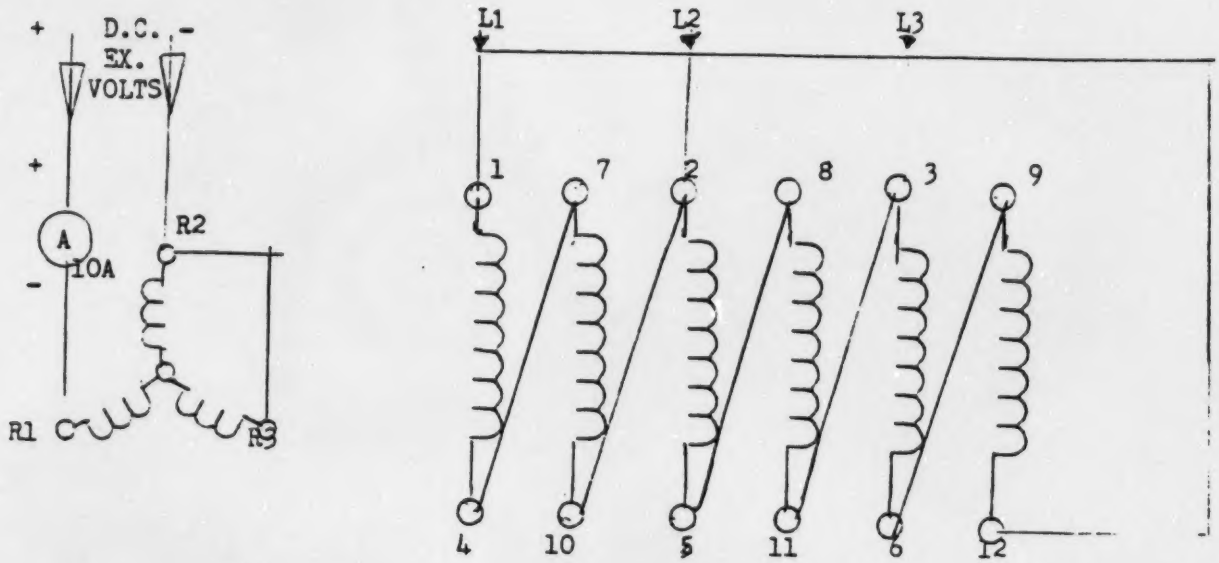
Mileaf: Electricity One-Seven. Hayden



D.C. SHUNT MOTOR CONNECTIONS



A.C. MACHINE CONNECTIONS Y (STAR)



A.C. MACHINE DELTA CONNECTIONS

CONNECTICUT STATE VOCATIONAL SCHOOLS

POLY-PHASE CURRENTS

Job Sheet 2
Page 1 of 2

Three Phase Circuits-Balanced WYE Connected Load

Purpose:

1. To determine the relation existing between line voltage and phase voltage in a Wye Circuit
2. To determine the relation existing between line current and phase current in a Wye Circuit.

Materials Used:

A. C. Voltmeter; 3 A.C. Ammeters; 3 lamp banks; 3 inductance cells

Source of Power:

3-Phase A.C. Supply

Explanatory Notes:

Just as three-phase alternators may be connected in either Wye or Delta, likewise the load on a three-phase system may be connected either Wye or Delta. Example: You will find later that some three-phase induction motors are Wye connected while others are connected in Delta.

Sketch:

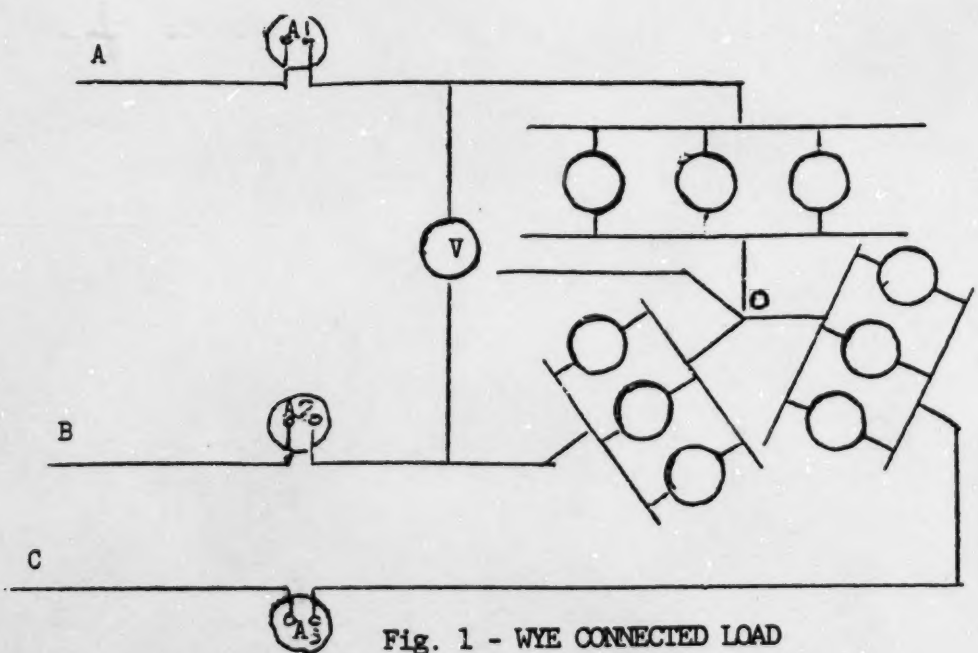


Fig. 1 - WYE CONNECTED LOAD

Procedure:

1. Connect three lamp banks in Wye (Y) as shown in Fig. 1.
   Adjust the lamp banks until all 3 ammeters read the same.
   Measure the line voltage (A to B, B to C, and A to C).
   Measure the phase voltage (voltage across each lamp bank).
   Record the ammeter readings.
2. Replace the three lamp banks by three equal inductance coils.

   Repeat the readings taken under Part "1".

   Tabulate your results as follows:

Load	Line Voltage	Phase Voltage	$\frac{\text{Line Voltage}}{\text{Phase Voltage}} = ?$	Line Current	Phase Current
Non-Inductive					
Inductive					

Questions:

1. For each set of readings divide the line voltage by the phase voltage. Record your answer in column 4 of the above table.
2. In a balanced Wye System, what relation exists between line voltage and phase voltage?
3. In a balanced Wye System, why is the line current and phase current the same?
4. If three 115 volt incandescent lamps are connected in Y on a three-phase system, whose voltage is 115 volts, will the lamps have full brilliancy? Give reasons for your answer.

References:

Jackson & Black - Elementary Electricity & Magnetism - Page 355
Slack - Elementary Electricity - Page 231
Swoope's Lessons in Practical Electricity - Page 515
Croft - American Electricians Handbook - Page 38

CONNECTICUT STATE VOCATIONAL SCHOOLS

POLY-PHASE CURRENTS

Job Sheet 3
Page 1 of 2

Three-Phase Circuits - Balanced Delta Connected Loads

Purpose:

1. To determine the relation existing between line voltage and phase voltage in a Delta Circuit.
2. To determine the relation existing between line current and phase current in a Delta Circuit.

Materials Used:

A.C. Voltmeter; 3 A.C. ammeters; 3 lamp banks; 3 inductance coils

Sketch:

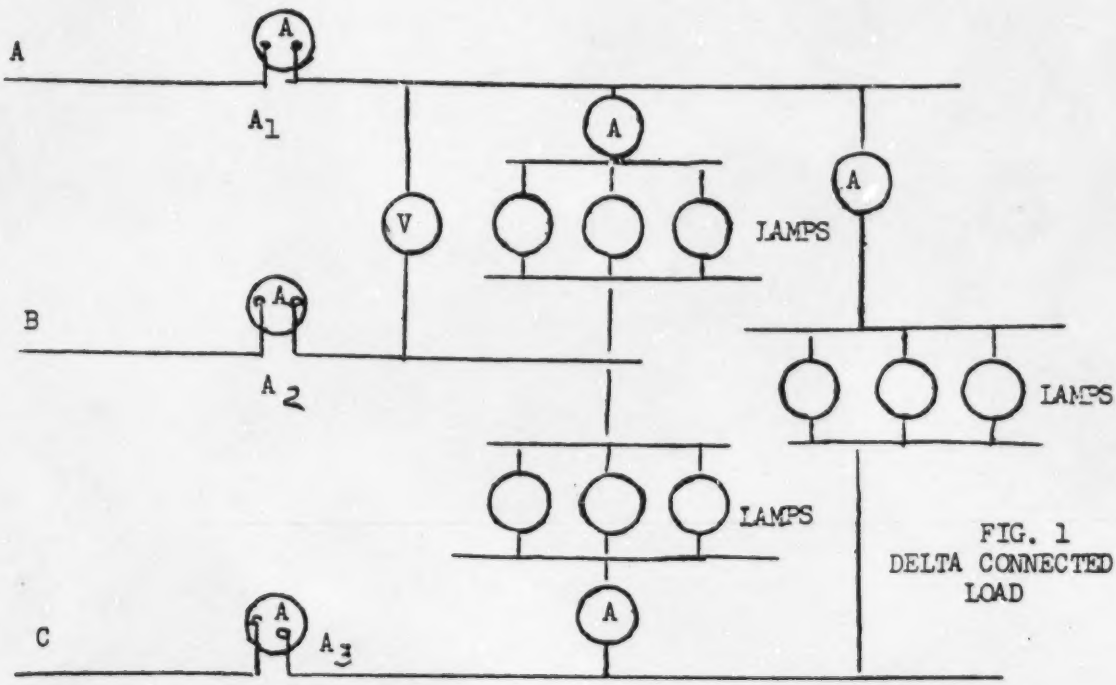


FIG. 1
DELTA CONNECTED
LOAD

Procedure:

1. Connect three lamp banks in Delta as shown in Fig. 1. Make provisions for measuring both the line and phase currents.

   Adjust the three lamp banks until all three line ammeters (A_1, A_2, A_3 of Fig. 1) read the same.

   Record the line currents A_1, A_2, A_3.

Insert an ammeter in each branch and measure each phase.

Record the line voltages AB, BC, and AC.

2. Replace the 3 lamp banks by 3 equal inductance coils. Repeat the readings taken under Part "1".

Tabulate your results as follows:

Load	Line Voltage	Phase Voltage	Line Current	Phase Current	$\frac{\text{Line Current}}{\text{Phase Current}} = ?$
Non-Inductive					
Inductive					

Questions:

1. For each set of readings divide the line current by the phase current. Record your answers in the extreme right hand column of the above table.

2. In a balanced Delta System, what relation exists between line current and phase current?

3. In a balanced Delta System, why are the line voltages equal to the phase voltages?

4. Compare Delta circuits and Wye circuits in regards to (a) voltages relations (b) current relations.

References:

Jackson & Black - Elementary Electricity & Magnetism - Page 355
Slack - Elementary Electricity - Page 231
Swoope's Lessons in Practical Electricity - Page 515
Croft - American Electricians Handbook - Page 39

CONNECTICUT STATE VOCATIONAL SCHOOLS

Information Sheet
Page 1 of 2

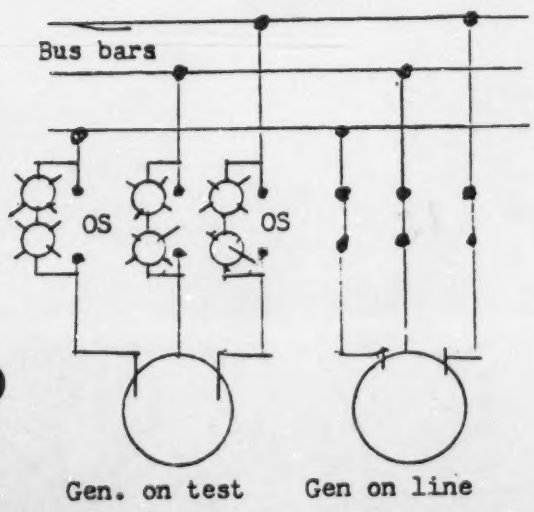
Operation and Paralleling of Alternators

In order to operate alternators in parallel we must have their voltages equal and in addition to this, the machines must be properly phased out and synchronized. These three conditions are the principal ones which must be observed before connecting any alternator in parallel with any other. Therefore, alternators must all be designed for the same voltage in order to operate successfully in parallel. Then the final adjustments can be made with the rheostats to exactly equalize the voltage.

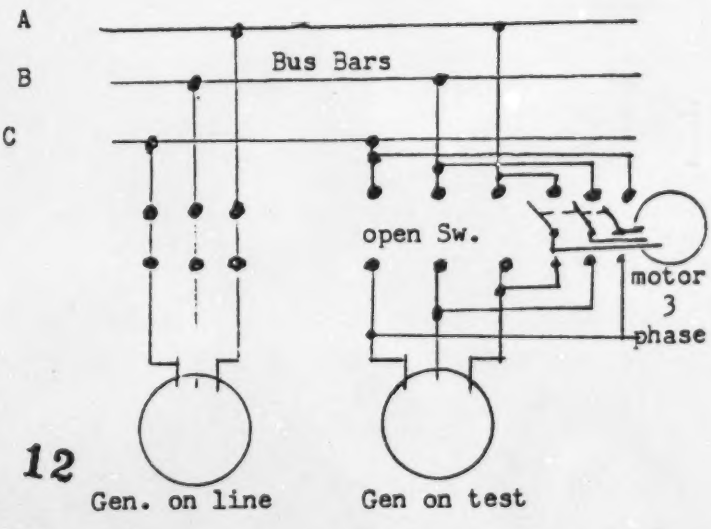
"Phasing out" consists of identifying the phases of the polyphase generators, in order to get the corresponding phases of two or more machines connected together. When connecting an alternator to others, each phase must connect to the corresponding phase of the other alternator: A to A, B to B, C to C. Methods used to phase out generators are the lamp method, the motor method, and synchronization method.

In the lamp method, lamps are placed across the open connections of the three pole, single throw switch. The switch is in the open position and the alternator is run. The speed of the alternator is regulated until the lights go off and on together. It can then be put on the line after synchronizing. If the lights do not burn bright and dim together it is necessary to interchange any two of the alternator leads.

In the motor method of phasing out, a motor is connected to the load of the generator on the line and to the generator coming on the line through a three pole double throw switch. The motor is connected to the knife blade contacts. With alternator on the line and the one coming on the line running, the motor is run through the switch, and direction noted. The double pole switch is then opened and the motor allowed to stop. The switch is then closed in the opposite direction and direction noted. If it is the same the generator phases are alright.



Light method - phasing in.



Motor method - phasing in

Operating and Paralleling of Alternators

A. C. generators must be carefully and accurately synchronized before being connected in parallel with other running generators. It is one of the most critical operations to be performed in a power plant and should be done carefully.

Synchronizing means to bring the generators into step or so that their positive and negative alternations occur at exactly the same time. On large machines this must be accurate to within a few degrees or heavy bucking currents can occur. If alternators were connected together when out of phase much damage could be done and short circuits occur.

The two most common methods for determining when alternators are in synchronism is the lamp bank and the synchroscope method. A synchroscope is the most reliable method as it shows if the incoming alternator is running too slow or too fast and indicates whether it needs slowing down or speeding up.

Parallel Operation of Polyphase Alternators

Purpose:

To parallel two polyphase alternators and to demonstrate the effects of various loads on their paralleled output.

Discussion:

The following steps are necessary in placing a polyphase alternator in parallel with other alternators across a bus.

1. The alternator is brought up to rated speed, and its effective line voltages are adjusted to the bus voltage by means of a voltmeter.

2. The phase sequence is checked by means of a phase-sequence indicator or synchronizing lamps.

3. The frequency of the incoming alternator is compared to the bus frequency by means of a synchroscope or a lamp method. If the incoming machine frequency is low, the prime-mover speed is increased; if high, the speed is decreased.

4. The paralleling switch is closed at the instant the lamps or synchroscope indicate that the phase-to-phase voltages are exactly equal and opposite. The incoming alternator is now floating on the line.

5. The alternator is made to take on load by increasing the speed of its prime mover.

6. The power factor at which the alternator carries reactive power is adjusted by means of its field rheostat.

7. The bus voltage is adjusted by adjusting all field rheostats simultaneously.

Apparatus Used:

2 REM-1 Motor Generator Sets; 2 REM-1C Consoles containing DC Machine Field Rheostat (250 Ω); DC Starter; 125 VDC Power Supply; 0 - 42 VDC Power Supply; 1 - AC Control Switchboard Section; 1 Loading Switchboard Section.

Procedure:

1. Connect each of the DC machines to operate as shunt motors as shown in Figure 19. Adjust the field rheostat to its minimum resistance fully CCW position.

2. Connect each of the AC machines to operate as 208 volt-3Ø alternators as shown in Figure 19.

3. Make the switchboard connections as shown in Figure 20. Prepare the switchboard as follows:

   A. Put all instrument switches to the off-position.

   B. Put the paralleling and field switches to the off-position.

   C. The AC machine field rheostat should be in its maximum resistance fully CW position.

4. Have the instructor check your connections.

5. Start one of the shunt motors and bring the speed up to 1800 rpm. Switch on the 42 volt DC excitation supply and close the field switch of the running alternator (henceforth, referred to as alternator #1). The field current will now be indicated on the DC ammeter.

   Adjust the field current to yield an output voltage of 208 volts. Switch on the output circuit breaker and add a 750 watt resistive load to the alternator. Maintain the 208 volt-60 cycle output by adjustment of the excitation and speed. Record the volts, amps, watts, power factor,and frequency in Table 21. Only one wattmeter and power factor are provided. These instruments are each provided with two switches and one removable (off-position only) handle. The meters will indicate for either alternator depending which one of its two switches is being operated.

6. Start the second shunt motor and bring the speed up to approximately 1800 rpm. Close the field switch of alternator #2 and adjust the output to 208 volts.

   The phasing lamps should now be flashing. If the lamps flash off and on alternately, the phase sequence of alternator #2 is incorrent. If the lamps flash off and on together, the phase sequence is correct.

   Adjust the speed of alternator #2 to decrease the speed of the flashes. When the flashing has been caused to stop so that the lamps are dark, the alternators are synchronized, that is, their voltages are equal and opposite.

   A more accurate way of determining the exact point of synchronism is the synchroscope. The synchroscope is controlled by two instrument switches and two removable keyed handles. Both handles fit either switch and each handle enables the operation of the switch to only one of its two operative positions. Turn the synchroscope switch of alternator #1 to the R (running) position. Turn the synchroscope switch of alternator #2 to the I (incoming) position. The resulting pointer rotation of the synchroscope indicates the difference in frequency of the two alternators. If the rotation is in the "FAST" (clockwise) direction, the incoming frequency (alternator #2) is too high. If the rotation

is in the "SLOW" (counterclockwise) direction, the incoming frequency is too low. The rate at which the pointer rotates indicates the magnitude of the frequency differential.

Close the parallel switch when the pointer is caused to stop at the index position. Alternator #2 is now floating on the line.

7. Adjust the alternator #2 so that it shares the load with alternator #1.

8. Decrease the load to 100 watts and vary it in several steps to 1500 watts. Record the volts, amps, watts, and power factor for each machine in Table 22.

9. Decrease the load to 750 watts and open the parallel switch. Alternator #2 is now disconnected from the line. Open its field switch and shut off its shunt motor.

10. If time permits, synchronize the two alternators again using the electronic switch and oscilloscope. Make the connections as shown in Figure 21. The connections should enable a dual trace of both alternator wave forms to be displayed on the CRT. Externally synchronize the oscilloscope sweep to one of the "SYN" outputs of the electronic switch. This will cause one of the waveforms to become stationary. The other alternator's waveforms will roll to the right or left depending on its frequency relative to the alternator. When this waveform is caused (by adjustment of the speed of alternator #2) to stop so that the waveforms are exactly out of phase, they may be paralleled.

11. If time permits, vary the power factor of the load on the paralleled alternators and note the results.

Report:

Prepare a formal report. Discuss in detail the methods used to synchronize the alternators. Discuss your experience in dividing the load between the two alternators. Plot the volts, amps, watts, power factor, and frequency for each alternator as ordinates versus the total output power as abcissa on one set of axes. How did the varying load affect the alternators?

Questions:

1. With the alternators paralleled, what would happen if one of the prime movers were shut off?
2. Can a synchroscope be used to check phase sequence?
3. What other methods can be used to check phase sequence?
4. What is synchronizing power?
5. What causes hunting or oscillation of alternators?
6. What are some methods of reducing hunting?

TABLE 21 ALTERNATOR #1

	L1-L2 VOLTS	L2-L3 VOLTS	L3-L1 VOLTS	L-1 AMPS	L-2 AMPS	L-3 AMPS	WATTS	POWER FACTOR
ALT. #1								

TABLE 22 PARALLELED ALTERNATORS

	L1-L2 VOLTS	L2-L3 VOLTS	L3-L1 VOLTS	L-1 AMPS	L-2 AMPS	L-3 AMPS	WATTS	POWER FACTOR
ALT. #1								
ALT. #2								

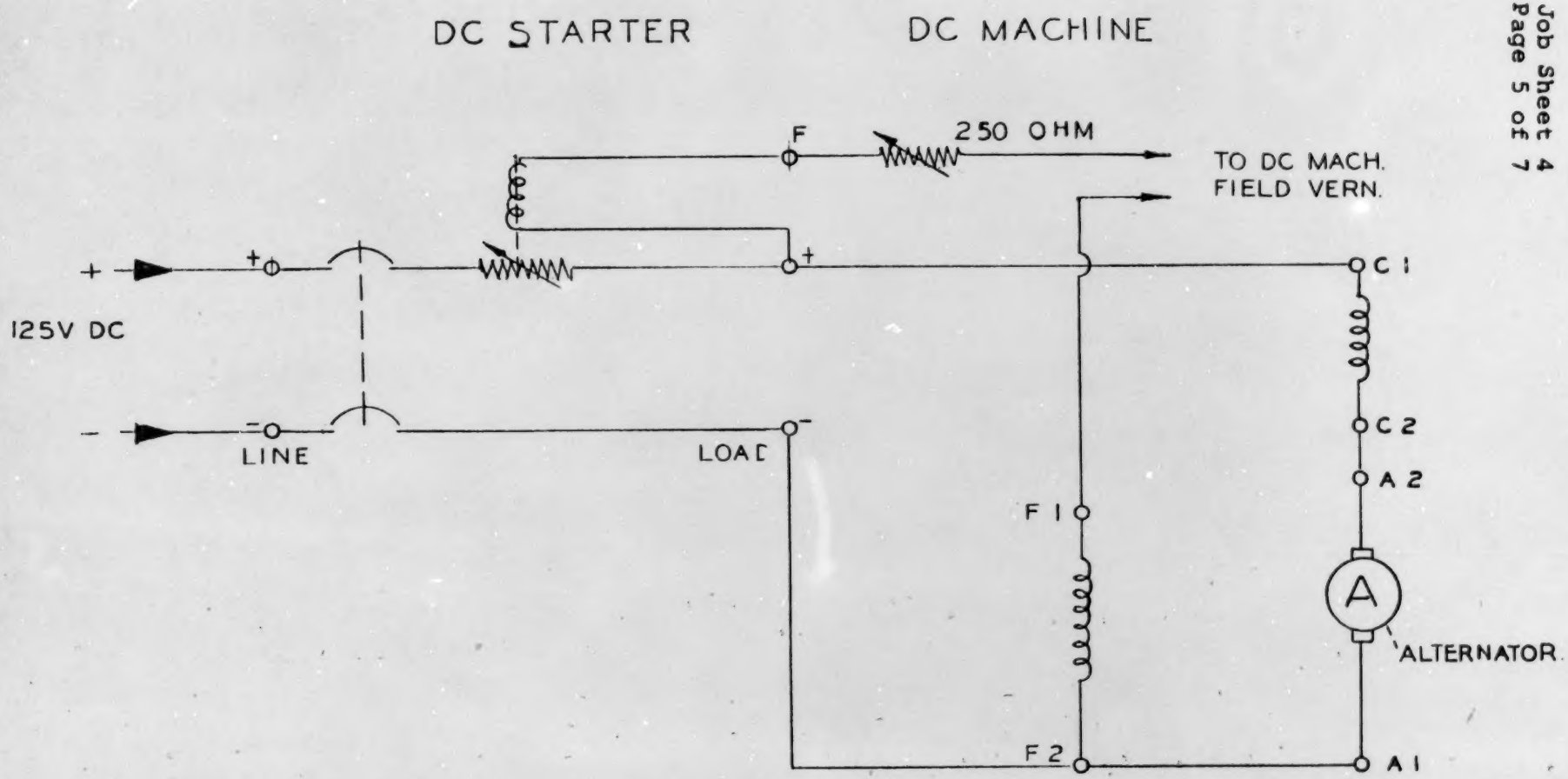


FIGURE 19
DC SHUNT MOTOR CONNECTIONS

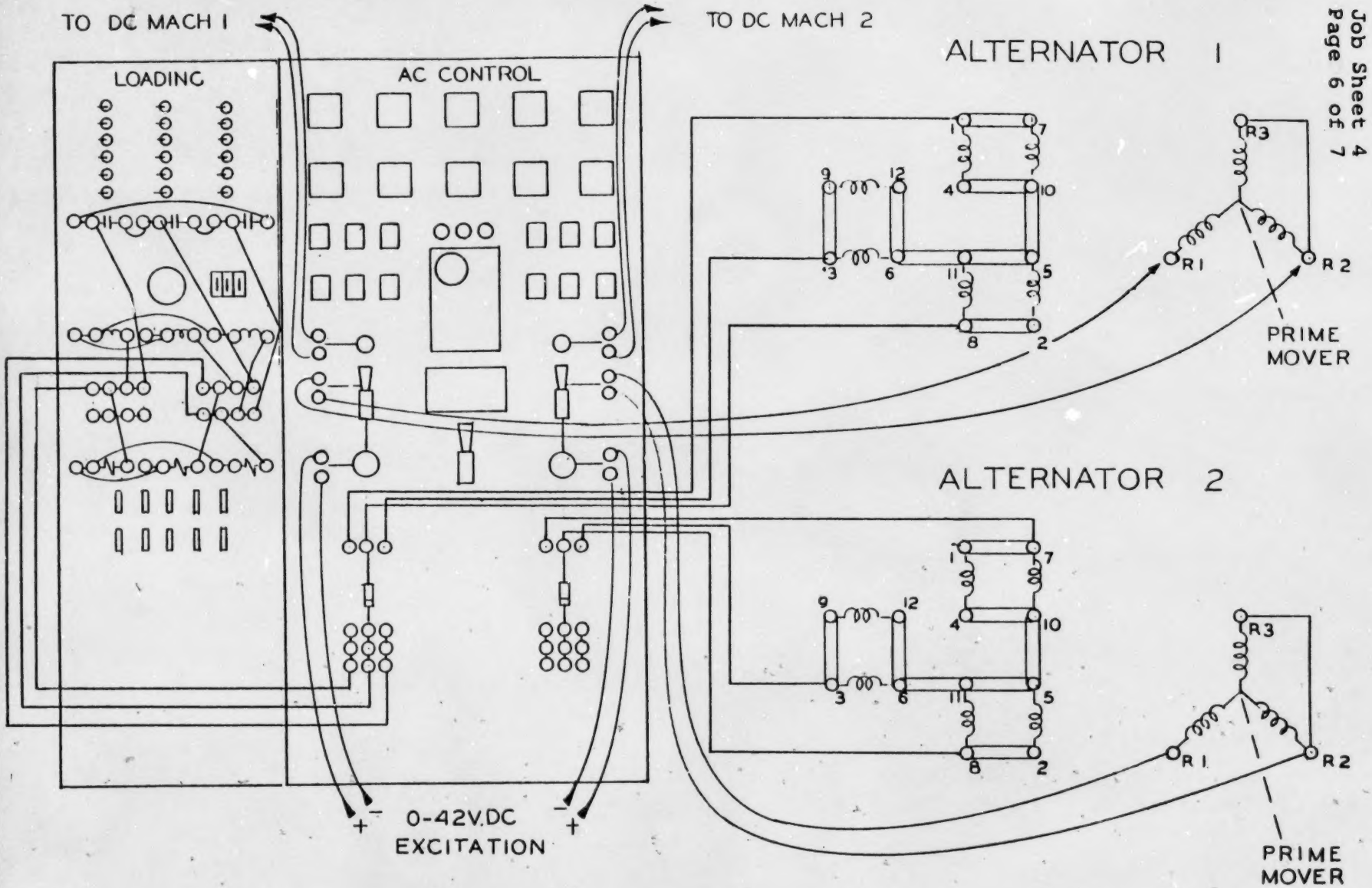


FIGURE 20 PARALLEL OPERATION OF ALTERNATORS

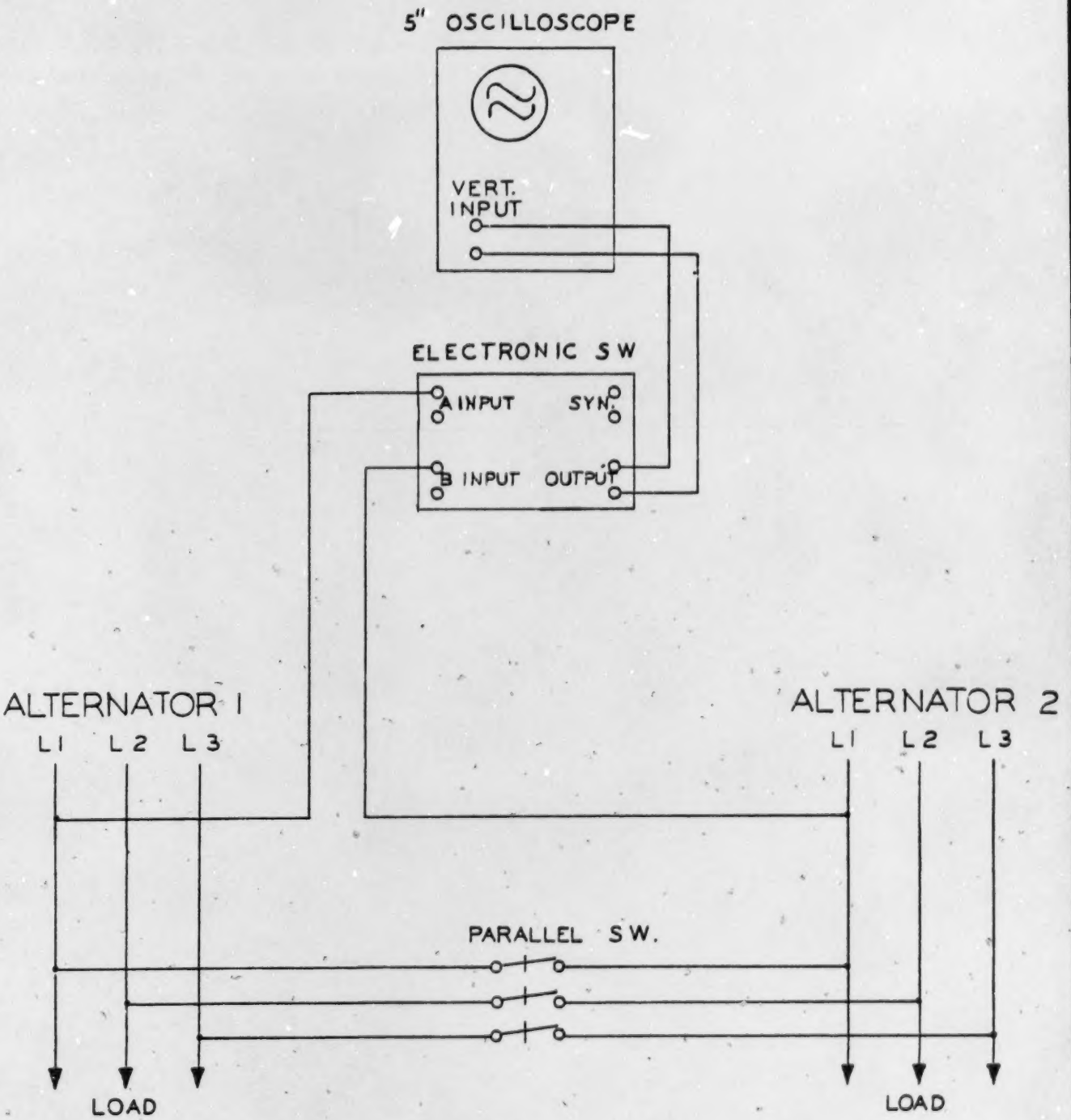


FIGURE 21[23]

OSCILLOSCOPE AND ELECTRONIC SWITCH CONNECTIONS

Synchronous Motors

Synchronous motors operate at synchronous speed, or in exact step with the applied frequency and rotating magnetic field of the machine.

When in normal operating condition, the synchronous motor has no slip, or "no slip" as it is often called. The speed of these motors is inversely proportional to the number of poles in the stator and directly proportional to the frequency of the applied voltage, and as long as the number of poles and frequency remain unchanges the speed will not vary.

Therefore, a synchronous motor is a constant-speed motor and can be used where a certain speed must be accurately maintained at all times.

Another great advantage of synchronous motors is that their power factor is very high, and they can actually be operated at leading power factor in order to improve the power factor on a system which is loaded with inductive equipment.

In many cases synchronous motors are only used for factor correction, and are operated without any mechanical load attached. In such cases the motors are connected to the system or lines and allowed to run idle or float on the lines, with their D.C. field poles strongly excited; so that they actually generate and feed leading current into the line and thus help to neutralize the effects of the lagging current produced by induction motors or other inductive equipment on the lines.

When these machines are used for power factor correction in this manner they are called synchronous condensers; because their effect on the system is the same as that of a static condenser, which also produce leading current.

Synchronous motors are made for power drives and power-factor-correction in sizes ranging from a few horse power to over 50,000 kv-a.

Synchronous motors are constructed almost the same as alternators; in fact. an alternator may in many cases be operated as a synchronous motor. Synchronous motors have an A.C. armature winding and a D.C. field the same as alternators.

Small synchronous motors are sometimes made with stationary field poles which are excited by D.C., and with revolving A.C. armature to which the line current is fed through slip rings.

Most medium and all large-size synchronous motors, are made with revolving fields, the same as large A.C. generators. On these motors the alternating current line energy is fed to a stationary armature or stator winding which sets up a revolving magnetic field, the same as induction motors. The field poles on the revolving field or rotor receive their D.C. exciting current through slip rings.

Synchronous Motors

As synchronous motors are always operated from alternating current lines, it is necessary to have some source of direct current for exciting their fields. This field supply is usually obtained from small D.C. exciter-generators, which are either mounted directly on the end of the synchronous motor shaft or may be belt-driven from a pulley on the shaft.

Synchronous Motor Connection

Purpose:

To study the method of starting a synchronous motor and to obtain the characteristic V curves of a synchronous motor.

Discussion:

Since the synchronous motor is inherently not self-starting, the motor must be brought up to a speed sufficiently close to synchronous speed in order that synchronism with the rotating field will occur. Various methods are employed to bring the motor up to speed. The method to be utilized in this experiment will be to start the motor as a squirrel-cage induction by connecting the three rotor slip rings to a wye connection of 3 ohm resistors. Once the motor comes up to speed, the DC excitation will be applied to the rotor circuit to cause synchronism.

In a rotating field synchronous motor, the three-phase current in the conductors of the stator produces a uniform rotating magnetic field rotating at synchronous speed. The north and south poles of the rotor, rotating at synchronous speed, are locked in synchronism with the synchronous rotating field of the stator. Thus, a rotor N pole is locked in synchronism with a stator S pole and vice versa, both rotating as synchronous speed. If a load is placed on the shaft of a synchronous motor, the countertorque created by the load will cause the rotor to drop back momentarily but continue to rotate at the same speed with respect to the rotating stator field.

If the countertorque is so great that it exceeds the maximum torque developed, and if the rotor slips out of synchronism, the synchronous motor will stop. Thus a synchronous motor will either run at synchronous speed or not at all. Indeed, as the rotor is slowing down, the rotating fields of the stator slip by the rotor field poles so rapidly that it is unable to lock synchronously. This is why a rotor at standstill is unable to start. At one instant, a rotor N pole is attracted to an approaching stator S pole producing a clockwise torque; and the next instant, the same rotor N pole is repelled in the opposite direction as the stator S pole passes producing a counterclockwise torque. The net torque is zero.

The operating characteristics of a synchronous motor are represented by a family of V-curves. These V-curves are obtained by applying a given constant load to the shaft of the synchronous motor and varying the field current from over excitation to under excitation, recording the stator current at each step.

Apparatus Required:

1 REM-1 Motor-Generator Set; 1 0 - 150 Volt DC Voltmeter; 2 0 - 10 Amp. DC Ammeters; 1 0 - 300 Volt AC voltmeter; 2 0 - 10 Amp. AC Ammeters; 2 0 - 1.5 KW AC Wattmeters; 1 REM-1C Console containing AC starter, Synchronous motor control, 208V-3Ø Power Supply, 125 VDC Power Supply, DC machine field rheostat, resistance load bank, and 1 0 - 42 VDC Power Supply.

Procedure:

1. Connect the AC machine to operate as a synchronous motor as shown in Figure 26. The current coils of all meters should be short-circuited when starting.

2. Connect the DC machine to operate as a shunt generator as shown in Figure 26. Adjust the shunt field rheostat to its maximum resistance position.

3. Have the instructor check your machine and meter connections before starting the AC machine.

4. With the switch in the "SYNCHRONOUS RUN" position, preadjust the DC field current to 8 amps. Change the switch to the "INDUCTION START" position and start the machine using the AC STARTER. When the machine comes up to speed, quickly change the switch to the "SYNCHRONOUS RUN" position, causing the machine to pull into synchronism.

5. Obtain data for V-curves for field currents from 9 to dropout for loads on the generator of 0, 500 watts, and 1000 kw. Record the data in Tables 30 - 32. When the machine drops out of synchronism, push the stop button and then restart as an induction motor at no-load.

Report:

Prepare a formal report following the suggested procedure for writing laboratory reports. Using the data in Tables 30 - 32, plot the stator current as ordinate versus the field current as abcissa for the no-load, half-load, and full-load conditions. Also plot curves of .8 lead power factor as dotted lines versus the field current on the same set of axes. Analyze your curves, comparing them to the results that one would expect considering the theory involved. Explain any sources of error in the results.

Questions:

1. Can an alternator be used as a synchronous motor? Explain.
2. Explain the method of bringing a synchronous motor up to speed.
3. What is a synchronous condenser? Why is it called this name?
4. What would be the effect of reducing the line voltage of the synchronous at a given value of load and field current? What would be the effect of increasing it?
5. Explain why the load angle must change when the load is increased.
6. How can a synchronous motor be used as a corrector of the power factor?

TABLE 30. NO-LOAD V-CURVE

FIELD AMPS	VOLTS	AMPS	AMPS	WATTS	WATTS	TOTAL WATTS	POWER FACTOR

TABLE 31. HALF-LOAD V-CURVE

FIELD AMPS	VOLTS	AMPS	AMPS	WATTS	WATTS	TOTAL WATTS	POWER FACTOR

TABLE 32. FULL-LOAD V-CURVE

FIELD AMPS	VOLTS	AMPS	AMPS	WATTS	WATTS	TOTAL WATTS	POWER FACTOR

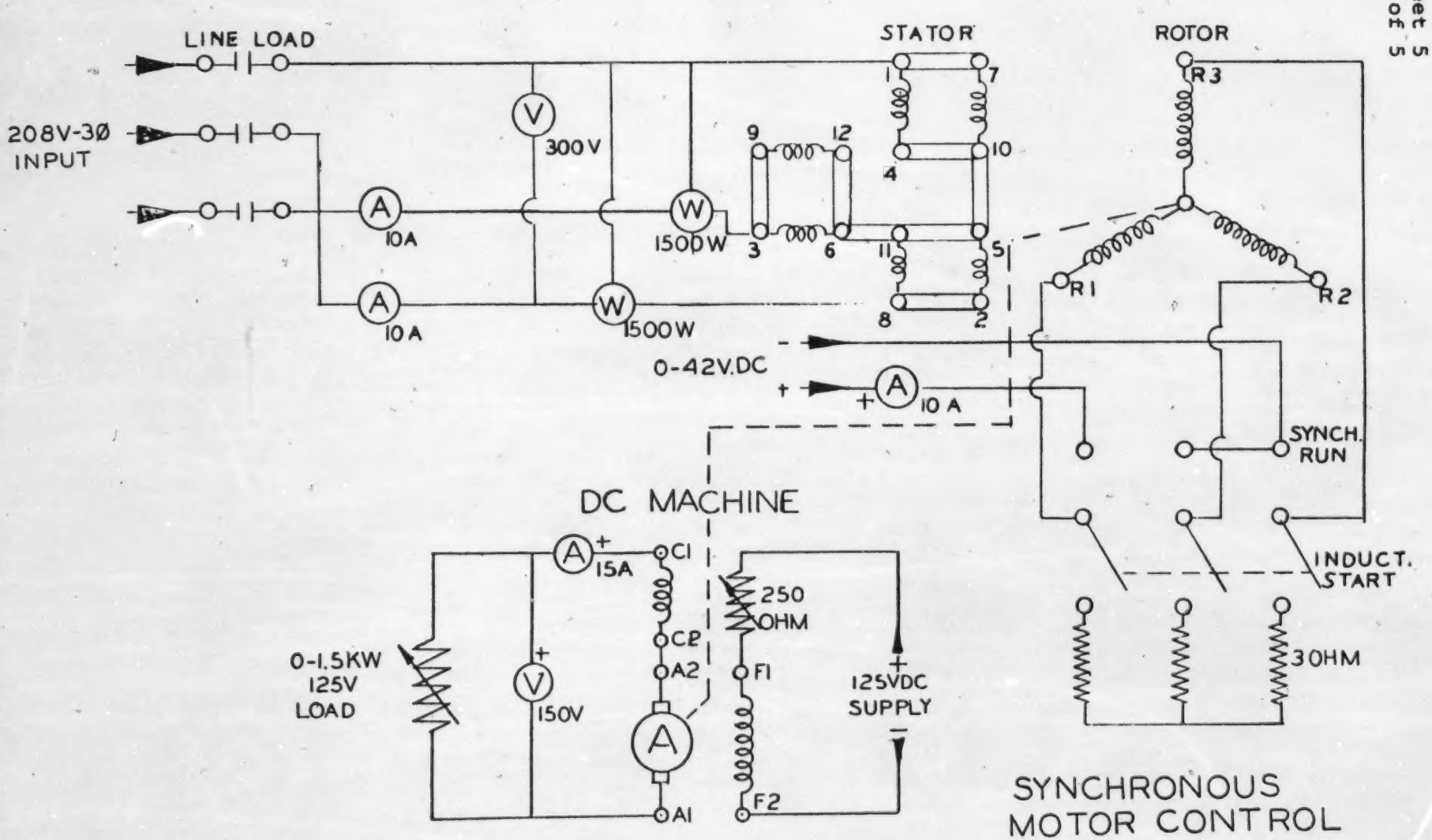


FIGURE 26
CONNECTION DIAGRAM FOR SYNCHRONOUS MOTOR